Examination of the Effect of Different Window Types on Energy Use in Turkish Apartment Buildings

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Abstract

In this study, the effect of different window types on energy use in Turkish apartment buildings is investigated. The example building is calibrated and used for analyses according to Turkish Insulation Standard TS 825 for the 5 different climate zones. In this study,, twelve different glazing types are selected for analysis. Also, the frame type changed to a PVC frame which is mostly used frame type in Turkey. As a result, the minimum heating loads are calculated for the W12 glazing type and the minimum cooling loads are calculated for the W1 glazing type. Thus, the U value is not the only value that affects the energy use intensity, solar heat gain coefficient (SHGC), and visible transmission (VLT) values are also important. Finally, the effect of glazing on the amount of CO2 emission is examined.

Keywords: Glazing, SHGC, Apartment Buildings, CO_2 emission, TS 2164, TS 825

I. Introduction

Today, global warming is one of the world’s major environmental problems and there are many ways to prevent it (Atmaca and Atmaca, 2015). As known, residential buildings play a significant role in the consumption of fossil fuels, and these fuels dominate the global energy consumption with a share of 81% and %40 of all primary energy used in buildings all around the world. Thus, residential apartment buildings represent an important opportunity to reduce the energy demand (Atmaca and Atmaca, 2015).

This study aims to improve the energy efficiency of residential apartment buildings in Turkey. There are 3 objectives for this study;

1- Selecting a representative apartment unit and characterizing it
2- Conducting a parametric simulation focus on window types
3- Develop design recommendations for different climate zones
4- Examination of the amount of CO_2 emission based on the different glazing types

Then, according to the results, we will evaluate the effect of windows types on building energy efficiency and analyze the effectiveness of the current Turkish Standard in terms of thermal transmittance, solar heat gain coefficient, and visible transmission values.

II. Methodology

II.I. Selection of the representative apartment building

According to the literature, there are three main approaches to create simulation models and these are theoretical reference models based on statistical data, a reference model based on one specific and monitored building, and ideal reference models based on experts’ estimation of input parameters. In this study, we choose an ideal reference model from a previous study to belong to Atmaca, 2015 (Fig 1). The details of the building are given in Fig 1.

Fig. 1: A general view and floor plan of the selected building (Atmaca and Atmaca, 2015).

II.II. Energy characteristics of selected building

The building is constructed in the urban area. Besides, it has a 7445 m^2 construction area, 13 floors, and 4 dwellings for each floor. 4 people live in each dwelling. The heating type is natural gas and each dwelling has a separate heating system which is the most commonly used system in Turkey (Table 1a). Also, the monthly average natural gas and electricity consumption values are given in Table 1b.

Table 1a. The properties of selected building

Specifications	Building
Number of floor	*13*
Const. area (m2)	*7445*
Floor height (m)	*2.8*
Total height (m)	*38*
External walls	*24 mm plaster / 150 mm concrete / 24 mm plaster*
Roof	*30 mm polyurethane / 150 mm concrete*
Windows	*4/12/4 double glazing with air*
Heating type	*Natural gas*
Lighting	*7 W/m2*
Equipment	*4 W/m2*
HVAC	*Mono split AC*
Occupancy	*4 person/dwelling*

Table 1b. The energy consumption values

Months	Natural gas consumption (m^3)	Electricity consumption (kWh)
January	*153*	*265*
February	*139*	*250*
March	*111*	*280*
April	*97*	*268*
May	*56*	*270*
June	*28*	*262*
July	*17*	*228*
August	*14*	*279*
September	*33*	*263*
October	*72*	*265*
November	*108*	*275*
December	*133*	*284*

II.III. Model creation and calibration

The simulations have been performed with the DesignBuilder and calibration was done according to ASHRAE Guideline 14 (ASHRAE, 2002). MBE is related to the average difference between the actual measured energy consumption data obtained for each month and obtained as a result of the simulation. It is calculated using the following equation:

$$MBE(\%) = \frac{\sum_{i=1}^{Np}(m_i - s_i)}{\sum_{i=1}^{Np}(m_i)} \tag{1}$$

CV(RMSE) represents the simulation models variability in the measured data and is defined as:

$$CVRMSE = \frac{\sqrt{\sum_{i=1}^{Np}\left((m_i - s_i)^2 / Np\right)}}{\bar{M}_p} \tag{2}$$

Here, Mp is the average of the actual values measured. Np is data numbers in the range "p", m_i is the measured values and s_i is the simulated values. When the monthly data are used for the calibration, the simulation model is considered calibrated if it has MBE that is not larger than 5%, and CV (RMSE) that is not larger than 15% (ASHRAE, 2002).

II.IV. Identifying the climate zones according to TS 825

The model was calibrated for Gaziantep province which is located in the 2nd climate zone. The other provinces selected to develop design recommendations for different climate zones are Izmir from the 1st zone, Istanbul from the 2nd zone, Ankara from the 3rd zone, Erzincan from the 4th zone, and Kars from the 5th zone. The weather data of selected zones were gathered from Meteonorm 8.3.

II.V. Properties of glazing and window types used in the simulations

The building has commonly used glazing and frame type which are double clear 4-15 with air (W1) and aluminum frame without thermal break. Then 11 more different glazing type is selected for analyzing the effect of different glazing types. The properties of selected glazings and frames are given in Table 2. Due to the TS 825 ignores the SGHC and VLT values, these values are taken as 0.763 and 0.712, respectively to simulate the model via DesignBuilder.

Table 2. The properties of glazing and window types used in the simulations (TS 825, TS 2164)

	Glazing type	*Ug (glass)value*		*Glazing type*	*Ug (glass)value*
W1*	Double glass 4-15-4 Air with Al frame	*2.7*	**W7**	Triple glass 4-9-4 Argon (coated) with PVC frame	*1.5*
W2	Double glass 4-15-4 SF6 with PVC frame	*2.5*	**W8**	Triple glass 4-6-4 SF6 (coated) with PVC frame	*1.3*
W3	Double glass 4-6-4 Argon with PVC frame	*2.3*	**W9**	Triple glass 4-12-4 Air (coated) with PVC frame	*1.1*
W4	Double glass 4-9-4 Air with PVC frame	*2.1*	**W10**	Triple glass 4-6-4 Krypton (coated) with PVC frame	*0.9*
W5	Double glass 4-6-4 Krypton with PVC frame	*1.9*	**W11**	Triple glass 4-9-4 Krypton (coated) with PVC frame	*0.7*
W6	Double glass 4-9-4 Argon with PVC frame	*1.7*	**W12**	Triple glass 4-12-4 Krypton (coated) with PVC frame	*0.5*

*The current buildings' glazing type

II.VI. Examination of the amount of CO_2 emissions based on energy consumption

Natural gas is used for heating and electricity is used as an energy source for the cooling period. For the CO_2 emission calculations, the emission value is taken as 0.202 kg/kWh for natural gas and 0.356 kg/kWh for electricity. (Dellano-Paz, F., 2015; EFDB, 2021).

III. Results

MBE and CVRMSE values were calculated as 3.79% and 7.47% for the heating period and 4.45% and 9.18% for the cooling period, respectively. According to these values, it can be said that the model can be used for simulations. After validated the model, the weather data were gathered for each different climate zones then simulations were made for each different glazing type. In the example building, the frame type was aluminum without a thermal break. In the simulated models, the most preferred frame type in Turkey was the PVC frame was used for simulations. Then heating loads (HL) and cooling loads (CL) were calculated (Figure 2). In the study, the indoor air temperature was accepted as 22°C for the heating period and 24°C for the cooling period.

The maximum yearly energy use intensity for heating was calculated between 69.2 and 83 kWh/m^{2}year for Kars province and the minimum was between 14.9 and 18.2 kWh/m^{2}year for Izmir province. When the glazing type changed, the energy use intensity decreased 16.6% for W12 glazing in Kars. When the results examined for Izmir which is located in the hottest climate zone, energy use intensity is decreased by 18% (Fig 2). According to these results, it can be said that a better U value is better to decrease the heating load of buildings.

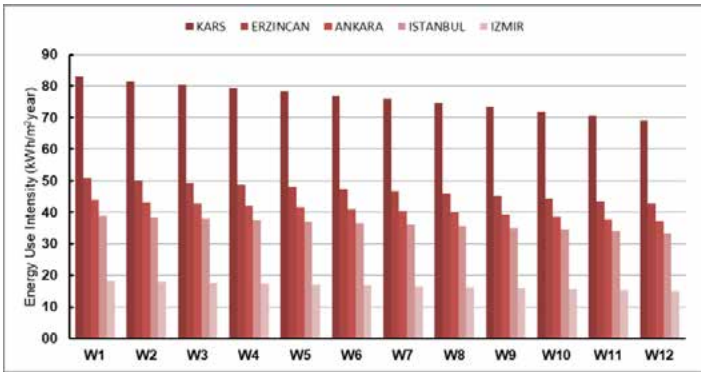

Fig. 2: The effect of the different glazing types on energy use intensity for the heating load (kWh/m^{2}year)

When examined the energy use intensity for cooling, it is not affected by glazing due to any need for cooling in Kars. The maximum yearly energy use intensity for cooling was calculated between 118.8 and 127 kWh/m^{2}year for Izmir province and the minimum was between 29.5 and 35.7 kWh/m^{2}year for Erzincan province. When compared to the base scenario (W1), the energy use intensity increased by 7% for Izmir province for W12 (minimum U value). For Erzincan, the W12 glazing type increased the cooling energy consumption by 21% (Fig 3). According to these results, it can be said that the U-value has an adverse effect on cooling loads.

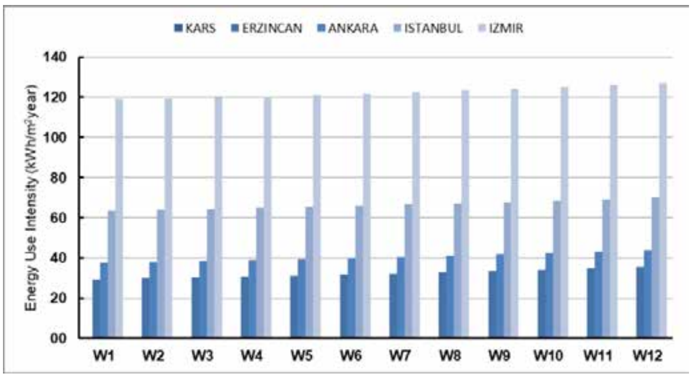

Fig. 3: The effect of the different glazing types on energy use intensity for the cooling load (kWh/m^{2}year)

In the base case (W1), depending on natural gas consumption for the heating period, the highest CO_2 emission was calculated in Kars with 109 tonnes/year and the lowest in Izmir with 23.8 tonnes/year. For heating season depending on the natural gas consumption for 12 different glazing types, the CO_2 emissions were calculated between 107.1 and 90.8 for Kars province, 65.6-56.1 tonnes/year for Erzincan, 56.7-48.8 tonnes/year for Ankara, 50.4-43.8 tonnes/year for Istanbul, 23.4-19.6 tonnes/year for Izmir. For cooling seasons depending on the electricity consumption, for base case (W1) the highest CO_2 emission was calculated for Izmir as 31.7 tonne/year and the lowest for Kars due to the no need for cooling. For cooling season depending on the 12 different glazing types the CO_2 emissions were calculated between 33.9 and 31.9 for Izmir, 18.7-17.1 for Istanbul, 11.8-10.2 for Ankara, 9.5-8.0 for Erzincan, and no emissions for Kars. When we examined the results for cumulative (total energy use); for the W1 base case, CO_2 emissions were calculated 109 tonnes/year for Kars, 74.6 for Erzincan, 67.7 for Ankara, 68.1 for Istanbul, and 55.6 tonnes/year for Izmir. Considering the heating period, it has been calculated that the highest CO_2 emission occurs in Kars, which is in the 5th climate zone, and the lowest CO_2 emission occurs in Izmir, which is in the 1st climate zone, depending on the natural gas consumption. Considering the cooling period, the highest electricity consumption was observed in Izmir, which is located in the 1st climate zone, and the lowest in Kars, where no CO_2 emissions occur. Considering the whole year, it has been calculated that the highest CO_2 emission value occurs in Kars in the 5th climate zone and the lowest in Izmir in the 1st climate zone, as in the heating period. This is because the heating period is longer and dominant for all climate zones.

IV. Conclusions and discussions

As known, TS 825 which was renewed in December 2013 takes into consideration only U values of glazings. However, when we examined the simulation results, U values are not the only value that affects the heating and cooling loads of buildings. Also, SHGC and VLT values are important. Thus, these values should be added to the TS 825. According to the results, there is no need for cooling in the 5th zone, however in the 2nd and 1st zone, the cooling loads are important; even so, Turkey is a heating-dominated country. If the SGHC values increase, the heat gains increase for the heating season. On the contrary, it has an adverse effect on cooling loads. For Kars which is located in the 5th zone and has no need for cooling, higher SGHC values will be better for heating-dominated provinces. Thus, the cooling and heating loads are not only affected by U values.

In the case of the base scenario (W1) of the sample building, in cases W2 and W12 where the heat transfer coefficient of the glass is reduced, natural gas energy consumption and CO_2 emissions during the heating period decrease by 17.7% in the province of Izmir in the 1st climate zone. During the cooling period, 21.1% of electrical energy consumption and CO_2 emissions increase in the province of Erzincan in the 4th climate zone. Considering the whole year covering the heating and cooling periods, it is calculated that total energy consumption and CO_2 emission reductions of up to 16.7% occur in the province of Kars in the 5th climate zone. Total energy consumption and CO_2 emissions decreased by 12.0% in Erzincan in the 4th climate zone, 10.5% in Ankara in the 3rd climate zone, 8.1% in Istanbul in the 2nd climate zone, and 3.7% in Izmir in the 1st climate zone. As can be understood from here, when the whole year is taken into account, it is understood that the total energy consumption and CO_2 emission value decrease more as one goes from the 1st climate zone to the 5th climate zone. The decrease in the heat transfer coefficient of glass and the decrease in energy consumption and CO_2 emission were most effective in Kars province in the 5th climate zones. The most important reason for this is that the heating period is longer and more effective in the 5th climate zone.

For future studies, we will examine the effect of SHGC values while considering the future climate scenarios. Also, the optimum glazing types for each zone will be analyzed.

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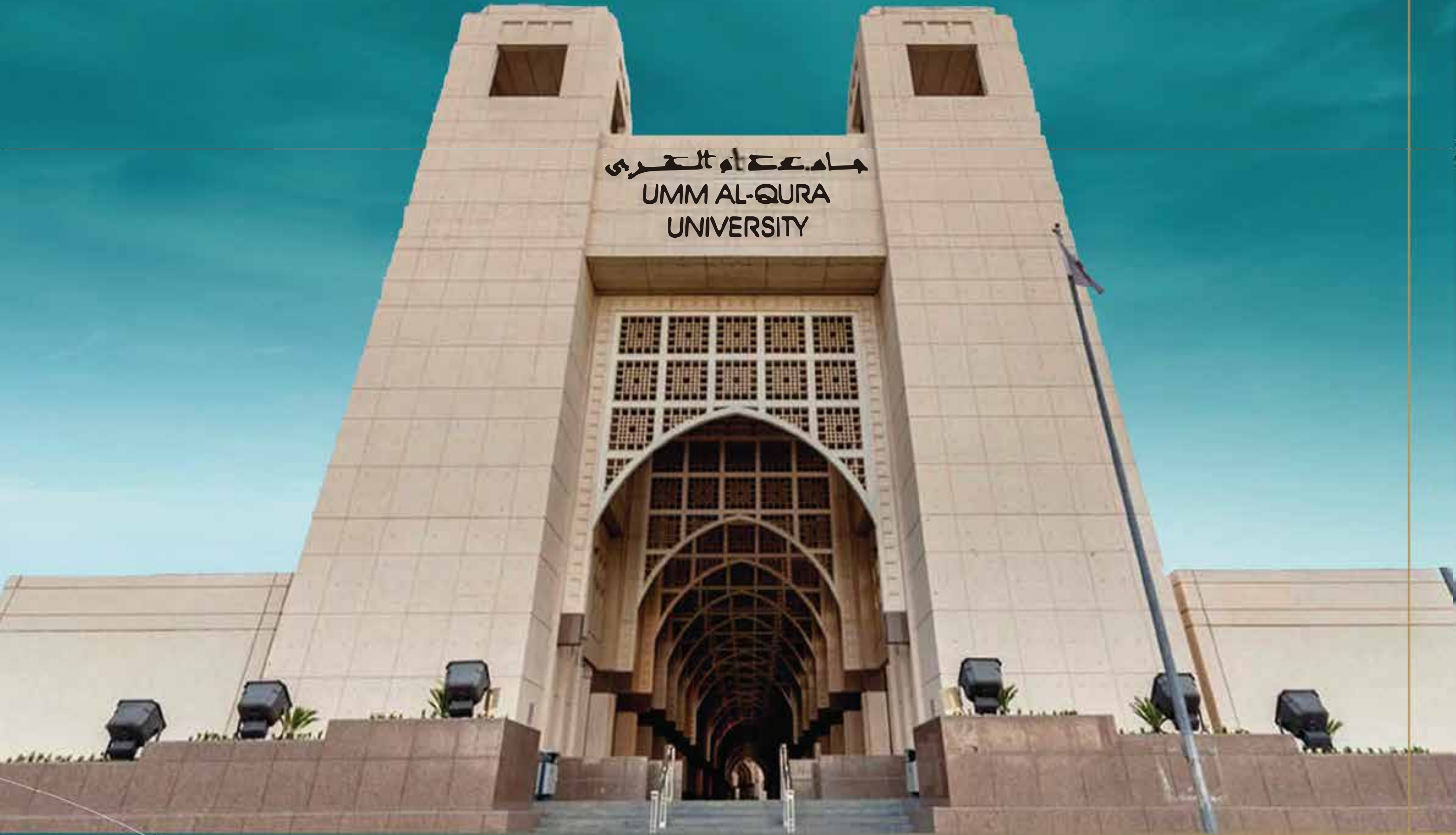

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